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METAL-MINE VENTILATION

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BY

D. HARRINGTON

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METAL-MINE VENTILATION

By D. Harrington[2]

Ventilation of underground workings consists of establishment of such control of air currents that the underground workers may work in safety, with maximum comfort and efficiency, and without impairment of health; and that the mine openings may be made subject to such control of air flow as to remove from the workings at ordinary times harmful gases and dusts, and at time of emergency, such as fire or explosion, there may be maintained as much or as little air flow as may be desired covering portions of the mine or the mine in its entirety.

Control of air flow is the keystone of any ventilating structure, and this very essential feature is obtainable only by the installation of mechanically operated fans, together with other ventilating devices such as doors, overcasts, regulators, etc. Every mine, large or small, coal or metal, should from the outset be equipped with a fan. While much has been written about natural ventilation and many claims have been made that in specific mines there is sufficient natural air flow, there are few if any mines, coal or metal, where natural ventilation supplies anything like adequately safe or healthful conditions for underground workers even at ordinary times; and at a time of mine fire or explosion the mines depending upon natural ventilation are practically helpless, and certainly are decidedly dangerous to those unfortunates forced to be in them.

While ventilation has practically always been deemed an integral part of coal mining, metal mines have rarely paid much, if any, attention to air circulation until forced to do so by occurrence of some untoward condition or accident. Yet metal mines actually have as great need of efficient circulation of air as have coal mines. The coal mine must remove the dangerous explosive gas methane, also fumes from explosives, and in occasional places other gases such as CO_2 or nitrogen; metal mines have greater necessity to remove fumes from explosives, frequently have occasion to remove CO_2, nitrogen, and other gases from strata, and even the coal miners' explosive gas, methane, is occasionally encountered; in addition, circulating air currents are urgently needed in many metal mines to reduce the excessively high humidity and

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temperature so frequently found in them but very rarely in coal mines. The immense quantities of minutely fine particles of rock-dust floating in the stagnant air of metal mines, which are very largely responsible for miners' consumption and other diseases so prevalent among metal miners in many regions, could be almost wholly removed by adequate ventilation. The generally accepted conclusion that coal miners have a healthful occupation and live to a ripe old age, and that many metal miners contract diseases such as lead poisoning, miners' consumption, etc., and either die early in life or are incapacitated in middle age, is due almost wholly to the superior working conditions in coal mines, chiefly brought about by ventilation.

Our larger metal mines are readily comparable in many respects to an immense office building or a hotel. The various levels correspond to the floors of the building, except that in a mine they are 100 or more feet apart vertically and in a building are 10 to 20 feet apart; the drifts and crosscuts correspond to the halls and corridors; and the raises, stopes and other working faces to the offices, sleeping rooms, etc.; there is the difference, however, that in the mine there are no openings to correspond to windows to the outside, and only too frequently no openings between working places corresponding to interior doors between offices or rooms, thus leaving only one opening to the working place. In general, the present practice even in the better ventilated metal mines is to cause currents of air to flow along the main drifts and crosscuts corresponding to halls and corridors of a building, with only such amounts of air going into the working places as might be expected to seep by diffusion into the rooms of buildings if all outside doors and windows were tightly closed and the one door to the hall left open. The workers are usually engaged in some occupation, such as drilling, timbering, shoveling, etc., which fills the air with fine dust (the most dangerous kind), or possibly they set off some dynamite to bring down rock or ore, liberating not only clouds of fine dust but also of smoke, laden with poisonous gases; and only too frequently the surrounding walls are damp and have a temperature of 80° to 100° F., or even more, and the stagnant air of the place has a temperature of 80° to 100° F. with a relative humidity of 90 to 100 percent.

The metal-mine underground worker frequently works daily under conditions analagous to those on the hottest, stillest, most humid day which can be found in any of our large cities and, in addition, he frequently has to breathe air laded with fine dangerous dust and with various quantities of poisonous gas, such as CO or oxides of nitrogen from explosives. The underground worker in some metal mines must pause several times daily to wring perspiration out of the few pieces of clothing he wears and even to pour perspiration out of his shoes from time to time. The ordinary condition of the underground metal mine working face often is similar to that which would be produced should all the windows of a sleeping room be closed tightly and air derived wholly from one open door to the hall, the resultant headache to sleepers from such situation being augmented for the miner by dust, gases from explosives and decaying timber, and possibly by high temperature and humidity, alleviated to only a slight extent by release of compressed air.

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It appears that approximately in order of their importance the main features affecting air in metal mines are: (1) Movement, (2) temperature, (3) relative humidity, (4) gases, and (5) dusts.

The matter of movement, or velocity, of air from the surface, through the working places, then back to the surface is by all means the most important consideration in effecting adequate ventilation of mines and in protecting the health and forwarding and maintaining the working efficiency of the underground workers.

Temperature of underground air is affected by outside air temperature in varying degree, dependent on depth and extent of workings, air velocities, and other considerations; temperature of mine air is very definitely affected by underground rock and water temperatures, by quantity of air flowing, by oxidation (or decay) of timbers and ores, and by mine fires. It is also affected to a greater or less extent by friction due to velocity of flow, by moving of ground, firing of shots, and heat from lights and from breathing of animals. Heated air obtained from other mines and from electric motors and other machinery may seriously affect the local temperature of air of underground workings.

Relative humidity of underground air is affected to some extent by humidity of surface air, but much more vitally by moisture content of walls of underground workings and especially by water dripping through the air. Quantity, temperature, and velocity of air flowing also ultimately affect the humidity of underground air. Handling of air by small fan and pipe units also locally affects mine air humidity and may be utilized to govern humidity of underground air to a certain extent.

Gases to be found in mine air may come from surface air, from breathing of men and other animals, from lights used, from firing of explosives, from compressed air used with machines or as blowers, from operation of various kinds of machinery, and from various rock or other strata encountered, as well as from mine fires that are active or incipient.

Dusts found in metal-mine air are largely derived from dry drilling, from blasting, from shoveling or mucking, from tramming or dumping rock or ore, timbering, etc. Probably well over 50 percent of all metal mines have siliceous material in ore or containing walls, and hence have siliceous dust, which as far as is known is the most dangerous of all dusts, especially when taken into the lungs in large quantities in the extremely finely divided form thrown into the air by dry drilling, blasting, and mucking. Certain siliceous dusts seem to have far less injurious effects than others of essentially the same composition. Dusts of other than siliceous character, while thought not to be so definitely and immediately dangerous, are nevertheless likely to be harmful ultimately, especially if present in the air in very finely divided particles and in large quantities; the dusts of certain soluble lead ores affect workers through skin absorption as well as through breathing.

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Below are some general conclusions of the writer on metal-mine ventilation, after many years of observation:

1. In mining, it appears that ventilation, fire protection and prevention, health, safety, and efficiency are very closely interlocked.

2. There is at least equal reason for providing adequate ventilation for most metal mines as for providing ventilation for coal mines.

3. Metal mines rarely, if ever, make provision for ventilation until forced to do so by some untoward condition or occurrence; coal mines, on the other hand, almost universally provide for ventilation.

4. Efficient ventilation of metal mines consists in supplying at all times such volume of circulating air at places where men work as will enable the worker to exert himself in comfort at maximum physical capacity without endangering his health.

5. Many, probably most, metal mining operating officials are ignorant of the principles of air circulation; this is true of those technically educated as well as of those without technical training.

6. Workers in metal mines, including shift and other bosses, should be educated to respect ventilating devices, such as doors, regulators, overcasts, brattices, fans, etc., as coal miners do, and to become as familiar with those devices as coal miners are. Many present-day reactionary metal miners and bosses consider ventilation a useless fad and obstruct rather than aid ventilation improvements.

7. Ventilation should be under definite, constant supervision, and preferably the person in charge should report to the highest officials, as many local officials in metal mines are not in sympathy with ventilation betterments.

8. Each mine should be ventilated wholly within itself; interventilation of mines is likely to be dangerous, inefficient, and unsatisfactory.

9. Every mine, coal or metal, should have a mechanically driven fan or fans placed preferably on the surface, fireproof housed, and capable of reversing air currents with minimum delay. Metal mines should provide fan ventilation from start of opening in order to avoid dangers from explosive fumes, dusts, heat, etc., and provide fresh air to workers.

10. At seasons of the year when the temperature of surface air and of underground rock and water are about equal, mines relying on natural ventilation are likely to have periods when air circulation is sluggish, or ceases utterly or reverses in direction.

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11. At time of mine fire, naturally ventilated mines are likely to be at a decided disadvantage through inability to control the direction of air currents.

12. There are records of naturally or otherwise inadequately ventilated mines filling with CO_2 or other gas, overcoming some of the workers (in some cases with fatal consequences) and compelling suspension of work for considerable periods of time. Upon establishment of efficient mechanical ventilation this situation is readily controlled.

13. Workers in many metal mines are much less healthy than workers in coal mines, due largely to the superior ventilation of the collieries.

14. Miners' consumption, the scourge of metal miners, is caused primarily by breathing very fine particles of certain mineral dusts and especially of siliceous dust. Over 50 percent of our mineral-producing mines are working in more or less siliceous material and through lack of ventilation are giving this dangerous dust maximum opportunity to exercise its harmfulness. Lead poisoning afflicts workers by skin absorption of soluble dust of lead ores as well as by breathing of such dusts.

15. The best remedy for the dust menace in mines, other than preventing its formation, is the universal coursing of currents of air to remove the dust, as it has been proved that the very fine, most dangerous dust in metal mines remains suspended in still air several hours.

16. Metal-mine dust, acting through miners' consumption, lead poisoning, bronchitis, etc., is the chief instrumentality in causing perhaps more deaths annually among the approximately 200,000 metal miners in North America than coal-dust causes to the approximately 700,000 coal miners through explosions.

17. It is fairly well established that miners' consumption is caused chiefly by siliceous dust, but it is probable that any kind of dust in large quantities in finely divided form in mine air will prove harmful to workers ultimately. Investigations in metal mines of the United States indicate that the air of mines so far studied is from 7 to over 40 times as dusty as in South African gold mines.

18. Intake air of metal mines is frequently dusty by having a crusher house or other dust producer near the collar of the intake air shaft, or by having ore skips or cars or ore dumping places in intake air passages without the slightest attempt to allay the dust produced or to prevent its entering the mine.

19. The dustiest, most unhealthful occupation underground is dry drilling, and the average dust content of air in places where this work is done in five large mines in various parts of the United States was 205 mg. per cubic meter of air, yet for similar work in South African mines, but using available

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precautions against dust formation, the dust content of air is said to be less than 5 mg. per cubic meter of air.

20. While there are regulations in many of the States of the United States to prevent dust formation in drilling, these regulations are not always lived up to. Miners, while recognizing the dangers from dust, often prefer to take the risk rather than endure the slight discomfort or extra trouble of using precautionary methods or devices; and mine and State officials appear to feel that unless the miner will willingly aid in protecting himself, they cannot force him to protect his own health and incidentally that of his family. Dust-prevention devices of proved success, such as present-day self-rotating wet stopers, should entirely supplant dry drills, and their use should be enforced upon both miners and operators in metal mines, as there is absolutely no valid excuse for dry drilling in present-day metal mining except in a very few instances. To date no workable device is available for removing dust in dry drilling in underground mines.

21. Spraying devices available to reduce dust while drilling may be effective if used intelligently; on the other hand, they may even intensify the air dustiness if used without intelligence, and unfortunately the latter is generally the case. Efficient water drills are now available for all purposes in metal mining (including efficient wet stopers for upper holes), and dry drilling should be prohibited.

22. Some metal mines with high dust production under certain conditions at working faces, have comparatively low dust content of the air in these places at other times, and have low average dust content of air in all places due to efficiency of ventilating currents, especially at working places. Significantly these mines appear to be singularly free of miners' consumption or other diseases, yet the employees work at top speed and the material handled is highly siliceous.

23. The use of poorly placed compressed-air hose blowers at working faces frequently intensifies air dustiness by allowing high-velocity compressed-air streams to pass through dry, loose, finely divided ore or other material being drilled, shoveled, or otherwise handled, and thus forcing workers to breathe this air highly impregnated with dangerous fine dust.

24. While finely divided dust in mines is probably the chief cause of miners' consumption, it is now recognized that there may be other factors of almost equal influence, such as high temperatures and humidities, harmful gases, and lack of air movement; all of these defects are readily remedied by ventilation.

25. It appears that with dry bulb temperature below 75° F., mine working places may be comparatively comfortable, irrespective of air movement or relative humidity. However, the presence of air heavily depleted of oxygen (say below 18 percent) or impregnated with gases such as CO_2, CO, oxides of nitrogen etc., any or all of which may be produced in blasting, may produce uncomfortable or unsafe conditions; also, such places may be both uncomfortable and unhealthful if large quantities of finely divided dust are present.

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26. With dry bulb air temperatures above 75° F., comfort and maximum working efficiency can be attained only when the air is moving, this being especially true if the air has high relative humidity. The exact velocity necessary is a variable dependent largely upon the temperature and humidity.

27. Saturated atmospheres, up to nearly blood temperature, may be made endurable, and even to a considerable extent comfortable, by providing sufficient velocity.

28. In still air in metal mines with a temperature of about 85° F. and 90 to 100 percent relative humidity, there is likely to be little effect on persons completely at rest, but upon doing even moderate work body temperature is likely to rise to over 100° F., blood pressure to fall perceptibly, and pulse beat to rise materially. In still air with temperatures of 90° to 100° F. and above 90 percent relative humidity, even when the body is practically at rest, body temperature rises quickly, reaching over 102°; blood pressure is likely to fall rapidly, pulse beat to increase abnormally and to be very sensitive to even slight exercise, perspiration to be very profuse, and dizziness, physical weakness, mental sluggishness, and headache are experienced; upon attempting even light work these symptoms are likely to be greatly augmented.

29. Relative humidity, even up to the saturation point, does not appear to be harmful to health, comfort, or efficiency until temperatures run above 75° F.; and if sufficient movement is supplied, high relative humidity is not particularly harmful until temperatures are well over 90° F.

30. With exception of blind-end working faces, metal-mine air in general is not particularly deficient in quality. However, blind-end faces of drifts, crosscuts, raises, winzes, and stopes in metal mines are likely to have air deficient in oxygen and high in nitrogen or CO_2, and possibly in CO, oxides of nitrogen, or other impurities. There are many cases on record of asphyxiation in metal mines from these gases.

31. Practically all of the explosives used in metal mines give off small percentages of poisonous fumes -- CO, H_2S, or oxides of nitrogen -- when fired, and SO_2 or SO_3 may be found when blasting ores high in sulphur content. If these fumes are not removed from confined working places by ventilation they cause headache, nausea, and even death. The gelatin dynamites give off a less quantity of dangerous gases than do the ammonium dynamites and the latter give off much less than the straight nitroglycerin dynamites; hence, the straight nitroglycerin dynamites should not be used underground, and all places using any kind of explosive should be thoroughly ventilated after blasting and before workers arrive. No blasting of any kind should be allowed during the working shift. Good ventilating currents should also be provided while shoveling blasted ore at the face to prevent workers from being affected by headache, nausea, or other illness from breathing explosive fumes stirred out of muck piles. Compressed-air hose blowers are ordinarily not particularly effective in removing explosives fumes.

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32. In stagnant air comparatively small quantities of impurities, such as 0.30 percent or over of CO_2, 0.02 percent or over of CO, or oxygen below 20 percent, cause headache, dullness, etc., and this is particularly true when temperatures are above 80° F. However, these small quantities of impurities are not likely to be very noticeable when there is perceptible movement of the air.

33. Frequently blind-end working faces in metal mines have air so depleted of oxygen that a candle will not burn and carbide lamps must be used; hence, oxygen is below 18 percent, and CO_2 may run several percent; occasionally entire mines are found with this condition, which many metal-mine managers hold to be perfectly all right. There is absolutely no question that men working in an atmosphere which will not support combustion of a candle cannot deliver maximum efficiency and that their health must ultimately suffer.

34. Mines with cool working places which allow men to work at top speed, especially when contracting, are likely to be extremely dangerous to health of workers unless provision is made to remove explosive fumes and other gases and fine dusts from working places by ventilating currents.

35. Mines with high temperatures, above 75° F., and high humidity, above 85 percent, are likely to lose from 25 percent to as much as 75 percent of the efficiency of workers, and workers are likely to become unhealthy ultimately unless moving currents of air are supplied to working places. Unhealthfulness and inefficient results are hastened and intensified if fine dust is present, especially siliceous dust, and if blasting is done, especially when men are in the mine.

36. Many accidents in metal mines are due to deficient ventilation. Failure to remove smoke and fumes from explosives prevents proper inspection of working places to make them safe, and, in addition, many men have been asphyxiated in explosives fumes; in hot, humid, stagnant air men are likely to be affected by dizziness or by lack of ability to think clearly or quickly, or they may faint at an inopportune time and be killed; also, there are numerous instances where men have been known to drop dead due to heart failure in these hot places.

37. When air temperature is over 75° F., the giving of air movement or velocity at working places is of more importance than any other consideration in giving adequate metal-mine ventilation, provided the air is reasonably free of noxious gases.

38. While variations in surface-air temperature and humidity may have a noticeable effect on mines with shallow workings, in general, they change conditions very little if at all at faces in mines with extensive workings; hence, underground working temperatures in large mines vary but little, due to outside air conditions.

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39. Air flowing in underground passages rapidly takes the temperature of the surrounding rock. The rate of change is variable and frequently is as high as, or higher than, 1° F. for every 100 feet of travel, even when air velocity is several hundred feet per minute. Still air underground rarely varies more than a few degrees from the temperature of the surrounding rock or water.

40. Rock temperature generally increases with depth, the rate of increase varying from 1° F. or more per 100 feet of depth in certain districts of the western part of the United States, to but ½° or 1/3° F. per 100 feet of depth in other regions, both of the United States and of foreign countries. In Montana, rock temperature in copper sulphide veins is about 108° F., at a point 3,800 feet below the surface, rate of increase being about 1° per 100 feet of depth. In a lead sulphide vein in the Coeur d'Alenes in Idaho, rock temperature 2,000 feet below the surface was but 50° F. In a Michigan copper mine with native copper ore, rock temperature was about 82° F. at a point 5,000 feet below the surface. In a gold-bearing quartz vein in Arizona the rock temperature was 90° F. at a point 600 feet below the surface, while in a quartz deposit bearing copper sulphide in another Arizona district, rock temperature 600 feet below the surface was but 70°. Temperature of coal in place in coal mines in the United States is rarely above 70° F. and is generally much lower. Magazine articles give the rock temperature of the Kolar gold field in India at 118° F. at a point 6,100 feet below surface, and give 98° F. at the 4,000-foot level of the St. John Del Rey mine in Brazil, while it is calculated that at the 8,000-foot level of the City Deep mine in South Africa the rock temperature will be but about 97° F.

41. Rock temperature may vary at the same depth in different kinds of material. A copper sulphide ore with quartz gangue in a mine in the western part of the United States had rock temperature several degrees higher than a zinc sulphide ore in quartz gangue in a parallel vein about 200 ft. distant, both on the same level and both practically free of water.

42. Water standing still or flowing on the floor in mines readily communicates its temperature to surrounding air; water dripping through the air quickly brings the air practically to temperature of the water drippers, and profuse water drippers will determine the temperature of the air almost irrespective of rock temperature. Water temperature underground is generally the same as that of surrounding rock, but not always.

43. Mines having rock temperatures, hence generally air temperatures, above 80° F., frequently have available water piped from the surface which is found underground with temperature below 70° F. Few if any mines take advantage of this water to cool the air by installation of sprays, yet this is a very effective method of reducing the temperature of the air. Mine managers state that they fear that water sprays will cause excessive humidity, forgetting that mines generally have the humidity anyway, and that if the air can be cooled to 75° or below and given a slight movement the high humidity is not harmful. Physiological experimental work in South African mines shows

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that men working in stagnant air with a relative humidity of 95 percent and a temperature of 87° F. increased the amount of work performed 46 percent by the mere expedient of installing a small fan to move or stir the air, showing that high humidity in itself is not particularly detrimental, at least until temperatures are well above 90° F.

44. Air passing through fans frequently has the dry bulb temperature increased several degrees Fahrenheit and the relative humidity automatically decreased. In one instance, an underground fan with air delivery of over 20,000 cubic feet per minute, had 3° higher temperature of air at delivery than at intake, the points of measurement being less than 50 feet apart. Similarly, small fan-canvas pipe units used underground for local ventilation frequently have delivered air several degrees higher in temperature than that of intake air at the fan.

45. Small electrically driven fans with galvanized iron or canvas or other flexible tubing are being widely used in metal mines to carry air to dead ends. The galvanized iron has the advantage of allowing reversal of air currents to pull smoke out after blasting, then to force moving air to workers after removal of smoke; moreover, it does not decay as fast as canvas. The flexible tubing must be, in general, used only in forcing air to the face, its advantages being low first cost, ready installation and removal, flexibility in conforming to bends or turns; and ease of repair. Moreover, because of its ready installation and removal, the flexible tubing can be brought close to the working face at ordinary times and easily removed prior to blasting to prevent its destruction. Either method readily admits of placing from 500 to 5,000 cubic feet of moving air per minute at the working face at comparatively small cost.

46. Compressed air from the end of air hose is used to a very great extent to remove explosives fumes from faces or to ventilate hot, stagnant blind-end workings in metal mines. These blowers deliver about 100 cubic feet of air per minute, but its temperature rarely varies much over 2° or 3° from the temperature of the rock and air of the working place. Such compressed-air blowers are inefficient as to removal of smoke or gases, provide comparatively little pure air, and give very little reduction in the temperature of the surrounding air. Moreover, it costs about 100 times as much to place 1,000 cubic feet of compressed air at a working place as to circulate a like amount of air by ordinary ventilation methods.

47. The use of electrical machinery underground causes considerable local increase of air temperature. A magazine article a few years ago described a proposed fan installation at a South African mine to force 75,000 cubic feet of air per minute from the surface into a mine for the sole purpose of ventilating the region around an electrically driven underground hoist, this air to be removed from the mine after passing through the hoist room.

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48. Cooling of air in mines is effected by use of ice or sprays of cool water, by refrigeration, by rapid coursing of air brought from the surface or carried through workings with cool walls, and by excluding air from abandoned workings and return air from currents of active workings. Water sprays are not employed nearly as much as they should be; ice is used to a slight extent in the United States but is probably employed much more extensively in South Africa; refrigeration is costly and found only in a very few mines; and the rapid coursing of air currents from the surface, which can be brought about most efficiently by the establishment of definite separate splitting systems, is used only occasionally, though it is quick, cheap, and efficient. Failure to seal abandoned places having decayed timber and hot rock or water sends much unnecessary heat into metal-mine air, and reusing of return air has the same effect.

49. At time of fire in a metal mine, lack of an efficient ventilation system may be disastrous. Each mine should have fans which should be so placed as to be inaccessible to fire, have fireproof housing, be capable of quickly reversing air currents if desired, and preferably installed on the surface. There should be a definite system of air splits such that fire in one place may not necessarily fill the entire mine with poisonous fumes. This provision is of vital importance, yet the writer knows of very few metal mines which have made even a reasonable attempt to establish this excellent safety feature. There should also be a system of doors near shafts in the levels leading from shafts such that the entire shaft may be readily isolated in case of fire, or any part of the mine may be isolated from the shaft.

50. Experimental work in mines reveals that after smooth-lining of shafts previously having ordinary exposed timbers there will generally be a reduction of friction to such an extent that 50 or more percent additional air can be handled by the same power. If the smooth lining is done with gunite, it also serves as a fire retardant. Preferably, at least the intake air shaft should be fireproof; and, if possible, all shafts or heavily inclined openings which carry air or through which men travel or are transported should be fireproofed.

51. While the cost of establishing a ventilation system for a large mine is variable, the cost of operation is not particularly burdensome. The operating cost will almost invariably be offset by savings, in compressed air and in increased efficiency and health of employees, which frequently will cover the entire cost of the investment within a few years. If a fire occurs, an efficiently installed and operated mechanical ventilation system is of incalculable value, and the absence of such a safeguard is likely to result in a heavy loss of property and possibly of life.

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